

# Detector-stable particle searches

**Andy Haas**

*New York University*

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<https://indico.bnl.gov/conferenceDisplay.py?confId=571>

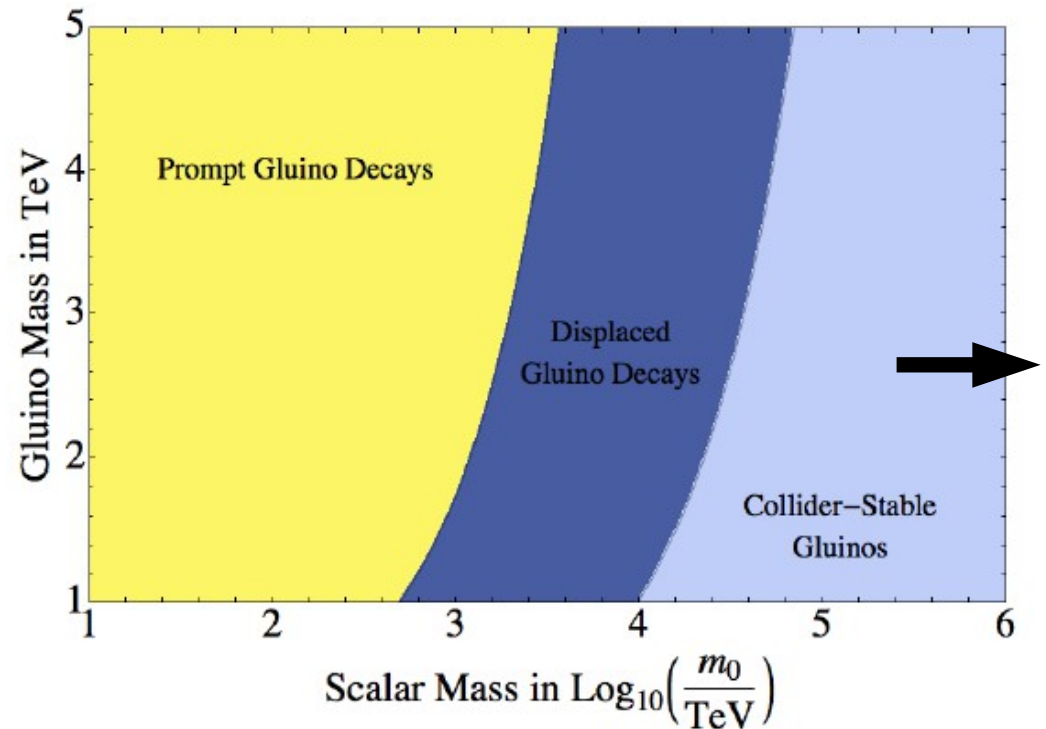


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# Introduction

- New particles will either be
  - Prompt decays
  - Semi-stable, decay in detector
  - Detector stable, decay outside the detector (or get stopped in the detector and decay later)
- Must ensure sensitivity to detector-stable case!
- Very well-motivated
  - SUSY NLSP with small  $\Delta m$
  - Split / mini-split SUSY
  - Magnetic monopoles
  - ...



# Benchmark scenarios

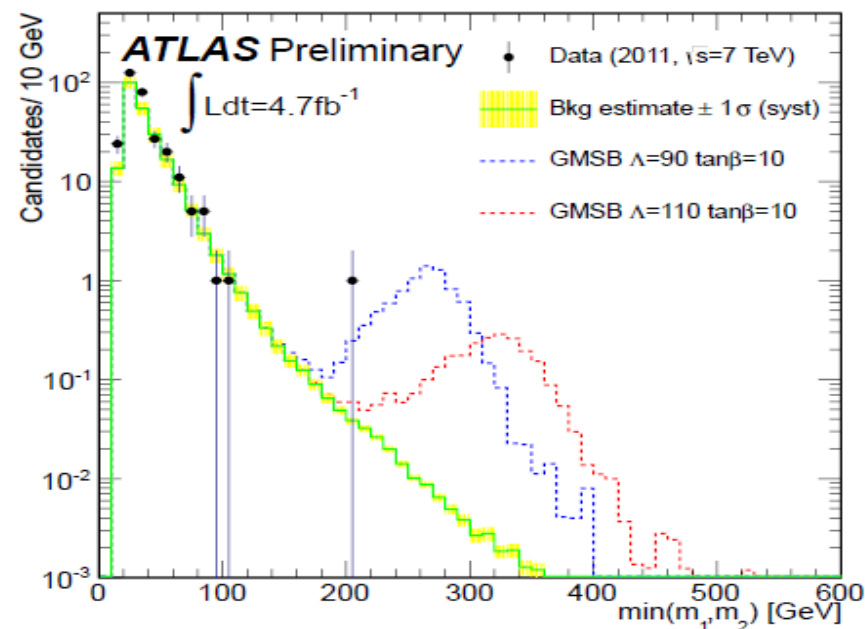
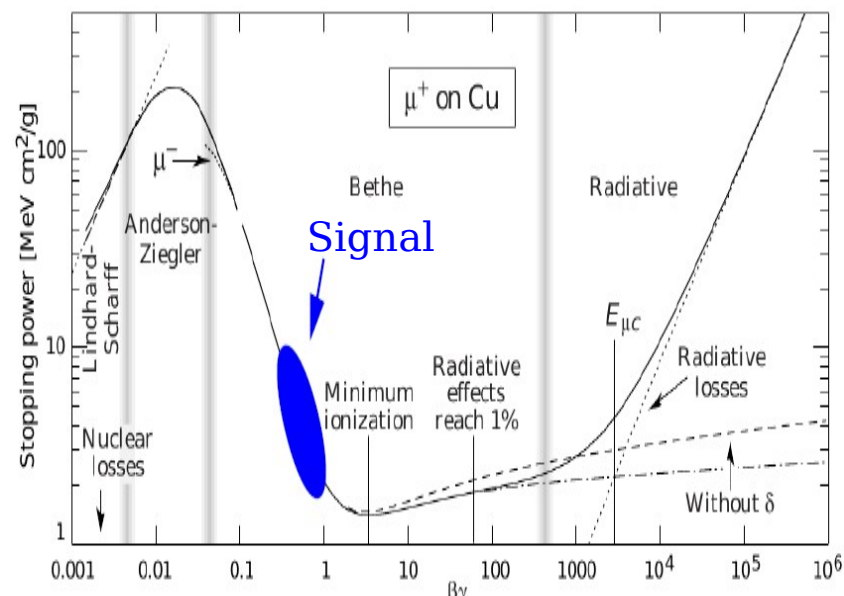
- 1) Colored (gluino, stop, sbottom)
  - Pair-produced via strong interaction (hadron collider) or DY (lepton collider)
    - Clearly a hadron collider will be better thanks to  $\alpha_{\text{Strong}}/\alpha_{\text{EM}}$
  - Hadronizes into “Rhadron”
  - May be electrically charged or neutral at production (hadron collider)
  - Charge exchange through nuclear interactions with detector material
  - “Generic, Regge, or Intermediate” benchmark Rhadron spectra / interaction models
  - a) Escapes detector
    - generally the discovery channel
  - b) Stops in detector ( $\sim 10\%$  of the time) and decays later
    - important for measuring properties: lifetime, decay channels, etc.

# Benchmark scenarios

- 2) Not colored, but electrically charged (stau, chargino, ...)
  - Pair-produced via DY (hadron or lepton collider)
  - Escapes the detector
    - Only a very small fraction would stop in the detector, unless they could be produced near threshold (lepton collider?)
- 3) Monopole ? (anyone covering this?)
  - Pair-produced via DY (hadron or lepton collider)
  - Large electric charge  $\sim 68.5 e$
  - Anomalous bending in magnetic field
  - Deposits energy in detector and stops, never decays

# Current searches / limits

- 2) Charged stable heavy particles
  - LHC currently has the best sensitivity
  - “Slow muon” signature  
High-pt central track ( $> \sim 50$  GeV)
    - Isolation from other high-pt tracks and jets
    - Measure *velocity* of track via
      - $dE/dx$  (inverting Bethe-Block) (measured best in silicon)
      - Precise timing (measured in calorimeters and muon systems)
  - Trigger on muon track or MET
  - Background: mis-measured leptons
  - $m(\text{stau}) > \sim 350$  GeV**



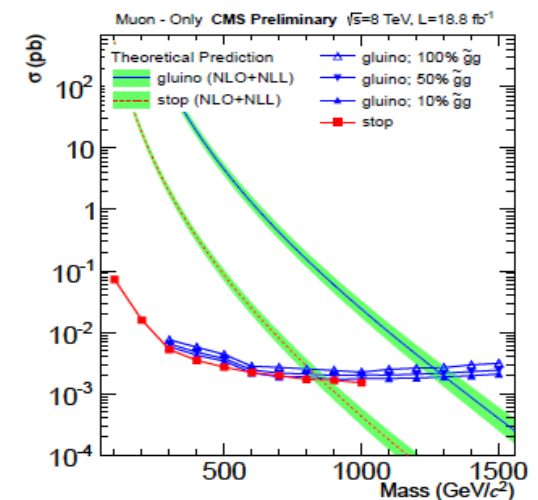
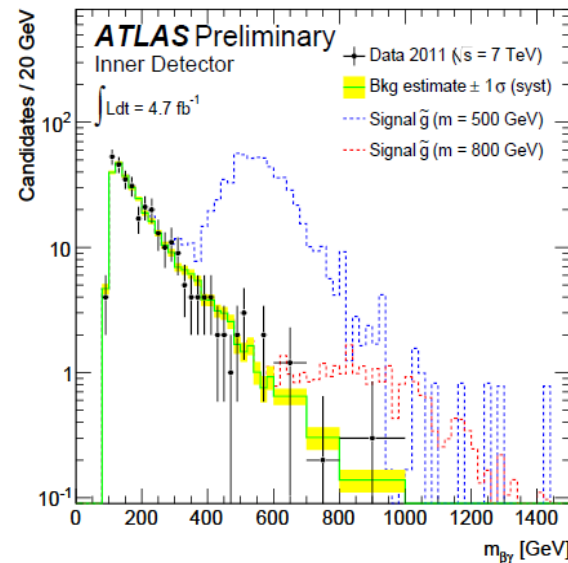
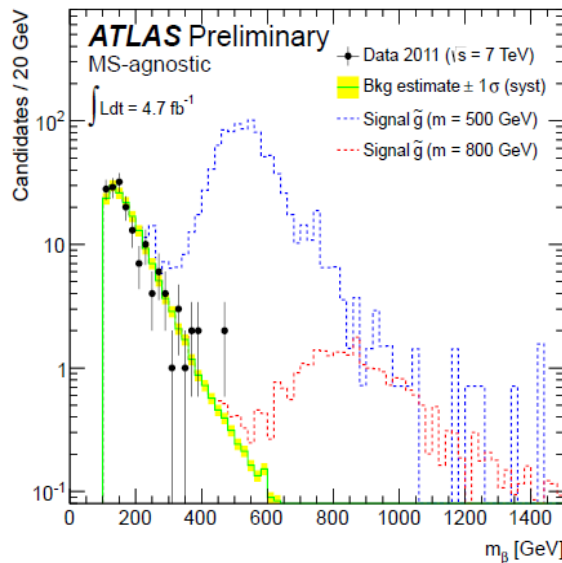
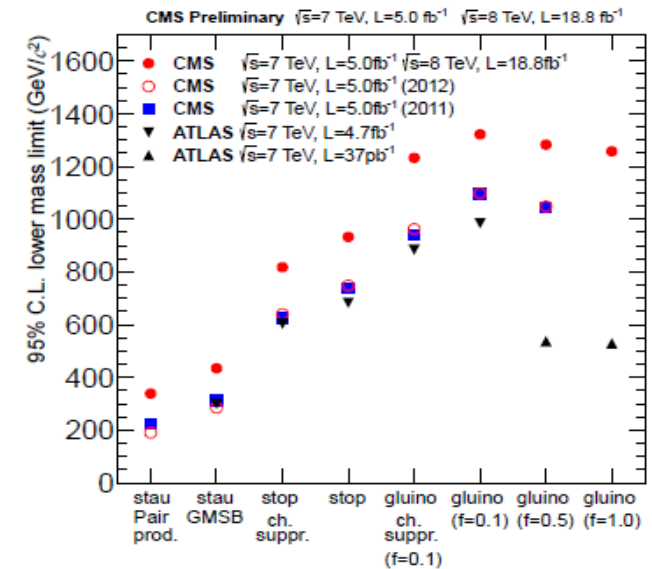
# Current searches / limits

- 1a) Rhadrons

- LHC also currently has the best sensitivity
- More complicated signature, may
  - become neutral in detector
    - Inner-track only + calorimeter timing
    - Inner-track only (use dE/dx only)
  - start neutral, become charged in calo
    - Muon-track only
- **$m(\text{stop}) > \sim 800 \text{ GeV}$ ,  $m(\text{gluino}) > \sim 1200 \text{ GeV}$**

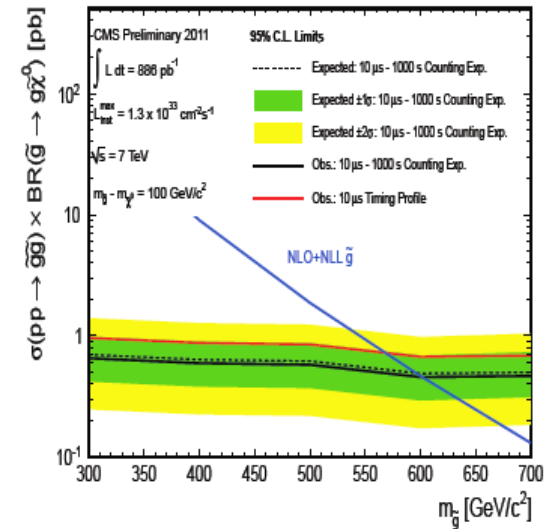
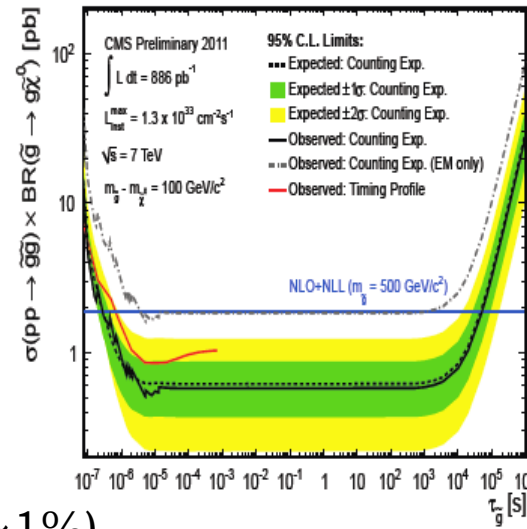
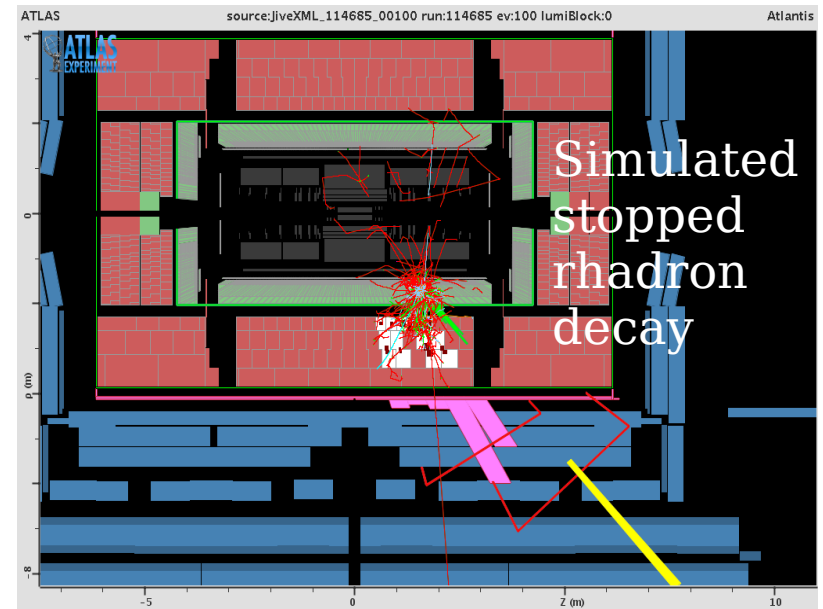
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CMS PAS EXO-12-026



# Current searches / limits

- 1b) Stopped Rhadron
  - ~10% stop in calorimeters
  - Look for decay during “empty” bunch crossings (abort gap, etc.)
  - Backgrounds: cosmics, beam-halo
  - CMS limits:  
 $m(\text{gluino}) > \sim 600 \text{ GeV}$   
 $m(\text{stop}) > \sim 340 \text{ GeV}$   
 for lifetimes of  
 $\sim 10^{-5} - 10^3 \text{ seconds}$
  - Much weaker than escaping Rhadron limits, but can see decay!
    - Important consideration for next experiments?
    - Sensitive to rare stopping ( $\sim 1\%$ ) of always-neutral Rhadron?

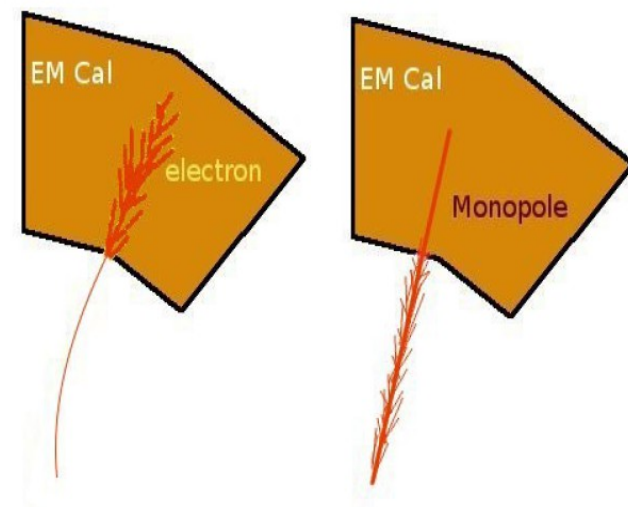
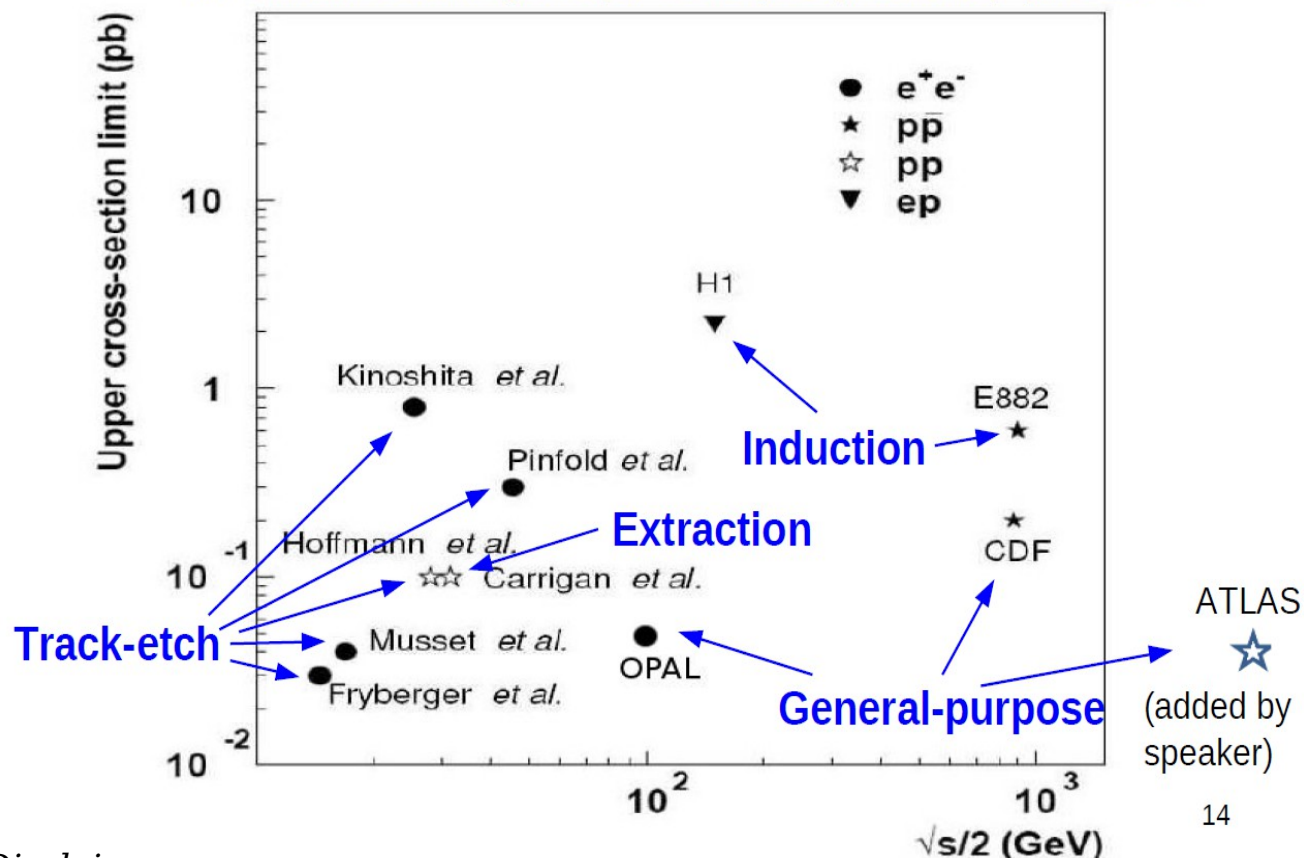


# Current searches / limits

- Monopoles

- Sensitivity to some models at LHC, important for future experiments?

M. Fairbairn *et al.*, Phys. Rept. 438, 1 (2007), arXiv:hep-ph/0611040



ATLAS-CONF-2012-062

Disclaimer:

Valid only in a given mass range for a benchmark model of monopole production.  
Monopole with charge equal to the Dirac charge.



# Simulation

- 1) Rhadron production and decays supported in Pythia 6 and 8
- 2) DY of stable, charged particles supported by many generators
- 3) Monopoles supported by many generators
  
- Rhadron and monopole energy loss / interactions supported by Geant4 extensions
  - No support in fast-detector simulators
  - Can mock-up some  $dE/dx$  and timing measurements / resolutions?
    - Tune to current LHC searches
  
- Generate various accelerator scenarios and compare expected sensitivities
  - Assume similar detector layouts,  $dE/dx$  and timing resolutions?
  - Study effects of machine backgrounds on resolutions and tails of  $dE/dx$  and timing?